

RESEARCH PAPER

Spray deposition on weeds of common bean crops

Andreia C. P. Rodrigues-Costa¹, Dagoberto Martins², Neumárcio V. Costa¹, and
Maria R. R. Pereira²

¹Centro de Ciências Agrárias, Universidade Estadual do Oeste do Paraná (UNIOESTE), 85960-000, Caixa Postal 91, Marechal Cândido Rondon, Brasil.

²Faculdade de Ciências Agrônômicas, Universidade Estadual Paulista (UNESP), 18610-307, Caixa Postal 237, Botucatu, Brasil.

Abstract

A.C.P. Rodrigues-Costa, D. Martins, N.V. Costa, and M.R.R. Pereira. 2011. Spray deposition on weeds of common bean crops. Cien. Inv. Agr. 38(3): 357-365. Weed control failure in common bean (*Phaseolus vulgaris* L.) production may be related to inappropriate herbicide application techniques. The purpose of this study, therefore, was to evaluate the amount of spray solution deposition that occurred on the weeds, *Bidens pilosa* L. and *Brachiaria plantaginea* (Link) Hitch., both within and between rows of common beans. The research was arranged in a randomized block design with four replications. The following 6 spray nozzles were used: flat fan nozzles XR 110015 VS (150 L ha⁻¹) and XR 11002 VS (200 L ha⁻¹); cone nozzles TX VK 6 (150 L ha⁻¹) and TX VK 8 (200 L ha⁻¹); and twin flat fan nozzles TJ60 11002 VS (150 L ha⁻¹) and TJ60 11002 VS (200 L ha⁻¹). The results showed that the loss of the spray solution on the soil occurred mainly within the bean rows and with a high intensity when using a nozzle spraying 200 L ha⁻¹. At 30 days after sowing, the TX (150 L ha⁻¹) nozzle was the only nozzle that promoted deposits of less than 210.0 µL g⁻¹ of dry mass. The spray nozzles showed a good performance in the deposition of the spray solution on the weeds that occurred both within and between the rows. However, for both species there was great variation in individual deposits depending on their location in relationship to the plants.

Key words: Application technology, *Bidens pilosa*, *Brachiaria plantaginea*, nozzle, *Phaseolus vulgaris*.

Introduction

Common bean is one of the most cultivated crops in Brazil, with three harvests per year that occur in different seasons. Regardless of its importance, the average yield in many regions is still low due to crop

management factors, including the interference of weeds (Maciel *et al.*, 2001); weed interference can decrease the yield of common bean crops up to 67% (Salgado *et al.*, 2007). Thus, the use of herbicides for the control of weeds in this crop can greatly improve its yield. However, there are few reports in the literature to support information about the spray technology of these chemicals (Cobucci and Machado, 1999; Tomazela *et al.*, 2006).

In common bean production, herbicide application techniques in different plant growth stages result in drift losses, ranging between 49 and 88% of the total applied product (Chaim *et al.*, 2000). In relation to the management of weeds, the product losses during the application, due to the inadequate technology of the application, may result in the failure of the weed control, the selection of resistant individuals to the herbicides and cause direct and indirect environmental contamination. In the specific case of herbicides applied in post-emergence stages, the best target deposition depends of factors, such as the application volume, nozzle type, angle of the nozzle, leaf morpho-anatomic structures, and architecture of the plant (Holloway, 1970; Taylor and Shaw, 1993; Berni *et al.*, 1999).

Significant interactions between the sprayed volume and the kind of herbicide used may occur (Knoche, 1994). However, the efficiency of the herbicide treatment depends on the quantity of the active-product deposited onto the plant and also on the uniformity and distribution of the product all over the target's surface with drops of adequate size.

The presence of weeds near crop rows can promote irregularities in the deposition of the drops, thus, an increase in the herbicide rate is always necessary. However, high levels of efficiency of weed control may be achieved under field conditions by improving the spray technology.

This study aimed to evaluate the efficacy of different nozzles and spray volumes on the spray deposition over *Bidens pilosa* L. and *Brachiaria plantaginea* (Link) Hitch. plants present within rows and between rows of a common bean crop (*Phaseolus vulgaris* L.).

Material and methods

One trial was carried out at the experimental farm of the Faculdade de Ciências Agrônômicas (FCA)

of the Universidade Estadual Paulista (UNESP), campus of Botucatu, Sao Paulo, Brazil; located at 22° 7'56"S, 74° 6'84" WGr, with an altitude of 762 m. The deposition of a brilliant blue dye sprayed on "Carioca" common bean plants and the increased occurrence of the weeds, *B. pilosa* and *B. plantaginea*, in areas of the bean plants were evaluated. The crop of common bean was sown on 02/09/2005, using 16 seeds m⁻¹, with spacing of 0.5 m between the rows. Fertilizer was applied at a rate of 160 kg ha⁻¹ using N-P₂O₅-K₂O fertilizer formula 04-14-08, according to a previous analysis of the soil. The crop was irrigated during the experimental period using a sprinkler system, every three days, with water blade of 20 mm.

The thinning of bean seedlings was performed at 7 days after sowing (DAS), leaving 11 plants m⁻¹. The plants of *B. pilosa* arose naturally during the experiment (i.e., without being planted), whereas, on the same day that the bean seeds were sown, 2.0 kg of *B. plantaginea* seeds were distributed in the entire area of the trial to guarantee the presence of this species in the area. The weed species in the area of each plot were manually removed weekly to avoid interference.

The trial was performed in a randomized block design with four repetitions, where each plot was composed of 6 crop rows of 5 meters long, totaling an area of 15 m². The Brilliant Blue food dye, FD&C-1, at concentration of 500 ppm, was used as a tracer to determine the spray deposition on the common bean and weed plants. The spraying of dye solution was performed at 30 DAS, when the common bean plants were at the V4 stage (three trifoliolate leaves), whereas the weeds were at stages of 2-3 pairs of leaves for *B. pilosa* and 3-4 tillers for *B. plantaginea* and average population densities of 51 and 112 plants m⁻², respectively.

The treatments were applied using a CO₂ pressurized sprayer, with four spray nozzles spaced at 0.5 m between them. The calibration conditions are presented in Table 1. The plots were protected by plastic divider boards (1.5 x 2.5 m)

during the spray application to avoid any drift to the neighboring plots. The environmental conditions during the applications ranged from 28.9 to 33.9 °C in the temperature and 53 to 65% in the relative humidity, and the average wind speed was 2.5 km h⁻¹.

Table 1. Spray calibration conditions used to obtain each spray volume studied.

Nozzles	Spray volume (L ha ⁻¹)	Pressure (kPa)	Speed (km h ⁻¹)
XR 110015 VS	150	175	3.6
XR 11002 VS	200	175	3.6
TX VS 6	150	500	3.6
TX VS 8	200	500	3.6
TJ60 11002 VS	150	175	4.8
TJ60 11002 VS	200	175	3.6

Plastic boxes with (dimensions of 11.5 x 11.5 x 3.0 cm) were used as artificial targets and placed in each experimental plot with the objective of assessing the amount of tracer deposited on the soil. The boxes were distributed before the application of the treatments along the four central rows of the plot, placing four plastic boxes in each row and four between the rows. Immediately after application of the dye spray, random samples were collected in each plot, harvesting 25 common bean plants and 25 plants of *B. pilosa* and *B. plantaginea* present in and between the crop rows. Subsequently, the dye tracer depositions were quantified with a double-axis visible UV spectrophotometer (GBC, model Cintra 20) for measuring the absorbance at a wavelength of 630 nm, according to the methodology described by Souza *et al.* (2007). The plant dry mass was determined by collecting the plants placing them in paper bags and drying in an air oven for 72 H at 65 °C.

The statistical analysis of the deposits on the common bean plants and weeds were conducted separately by comparing the performance of the studied nozzles, by species, to avoid interference of the different stages of development (Souza *et al.*, 2007). For *B. pilosa* and *B. plantaginea* we used a factorial double 6 x 2 (6 nozzles x 2

positions - weeds located in rows and between the rows) design. We used a factorial double 6 x 2 (6 nozzles x 2 positions - collectors positioned in the rows and between the rows) for the spray deposition on the soil. The results of the deposits, expressed in µL g⁻¹ of dry mass, as proposed by Maciel *et al.* (2001), were submitted to an analysis of variance by the F test, and the means were compared by the LSD test (P≤0.05) using the statistical program, SISVAR 5.0.

Results and discussion

The mean values of the spray that reached the soil both within and between the rows of the common bean crop after the treatment application are presented in Table 2. It is noteworthy that depending on the purpose of spraying may consider these results as a loss by drift. There was no statistical difference in the interaction between the nozzles and the position of the artificial targets. However, considering the mean of all of the nozzles and spray volumes, it was observed that the drift between the rows was 90.4% higher than those obtained within the rows at 30 DAS. Similarly, Berni *et al.* (1999) did not find differences in the drift of the deposits on the soil within or between the rows of a crop of common beans at 63 DAS using flat fan nozzles (models 110°-SF-01 and 110°-SF-02) or cone nozzles (D2-23 and D3-25) with spray volumes of 200 L ha⁻¹.

The XR, TX and TJ60 nozzles with spray volumes of 200 L ha⁻¹ resulted in average losses of 66.5, 69.4 and 68.1%, respectively, when compared to the total volume sprayed; for volumes of 150 L ha⁻¹, the average soil deposition provided by the XR, TX and TJ60 nozzles were 67.9, 67.3 and 65.4%, respectively, when compared to the total volume sprayed. It was observed that the XR nozzle at a spray volume of 200 L ha⁻¹ promoted drifts of 28.2, 26.7 and 22.5% higher than the XR, TX and TJ60 nozzles, respectively, at a spray volume of 150 L ha⁻¹. According to Bauer and Raetano (2003) and Raetano and Bauer (2004), the use

Table 2. Mean values of the spray deposition on the soil within and between the rows of a common bean crop at 30 DAS.

Nozzles	Spray volume (L ha ⁻¹)	Row	Between row	Means
		(L ha ⁻¹)		
XR 110015 VS	150	30.76	65.39	48.07 c
XR 11002 VS	200	54.86	79.00	66.93 a
TX VS 6	150	33.05	65.07	49.06 c
TX VS 8	200	38.29	84.12	61.21 abc
TJ60 11002 VS	150	36.78	66.90	51.84 bc
TJ60 11002 VS	200	41.08	86.69	63.88 ab
Means		39.14 B	74.53 A	
F _{Nozzle} (N)	2.796*			
F _{Position} (Po)	78.923**			
F _{(N) x (Po)}	0.797ns			
F _{Block}	2.178ns			
LSD (row)	8.105			
LSD (column)	14.039			
CV (%)	24.280			

Means followed by a different capital letter in a row and the are different lower case letters in a column (LSD test, $P \leq 0.05$).

*Significant ($P \leq 0.05$).

**Significant ($P \leq 0.01$).

ns: not significant.

of fans to inject air in spray bar to 26 days after emergence (DAE) of bean plants can provide up to 60% loss of volume applied to plants.

Thus, in the applications of herbicides to control weeds at the post-emergence stage, a residual effect of the product could also be the elimination of the seed bank in the area. Alternatively, the residual effect on the soil of some post-emergence herbicides could either control the weeds or reduce the seed bank in the areas of the common bean crop.

We found that the nozzles provided spray depositions that were similar to each other. Only the XR nozzle (200 L ha⁻¹) showed a superior performance, with a spray deposition 39.4% higher than the lowest that was observed (Table 3).

According to Maciel *et al.* (2001), spray applications performed with the XR and TX nozzles without surfactant resulted in increases of 106.4 and 66.9%, respectively, on the spray deposition

over common bean plants when compared with the same nozzles spraying mixes with the surfactant, Aterbane BR, at 0.5% v v⁻¹. The authors propose that this may have occurred due to of the lack of adherence of the drops on the leaves owing to the reduction of the surface tension of the liquid by the inclusion of the surfactant.

At 30 DAE, Cunha *et al.* (2005) found 21.5 and 61.1% more drop deposition in the upper and lower parts of bean plants, respectively, using a spray volume of 250 L ha⁻¹ instead of 125 L ha⁻¹. The authors also observed that the droplets formed in the applications using the hollow cone nozzle (ATR - Alumina Turbulence) were more likely to drift than those produced with the flat fan nozzle (API - Alumina Plastic ISO), especially when using low spray volumes. Similarly, Raetano and Bauer (2004) found that there was no effect of air assistance along the spray bar on the levels of the deposits on bean plants at 26 DAE; in general, the treatments with higher volumes of applica-

Table 3. Mean values of the spray deposition on common bean plants at 30 DAS.

Nozzles	Spray volume (L ha ⁻¹)	Deposits (μL g ⁻¹ dry mass)
XR 110015 VS	150	230.64 ab
XR 11002 VS	200	286.83 a
TX VS 6	150	205.76 b
TX VS 8	200	243.55 ab
TJ60 11002 VS	150	224.32 ab
TJ60 11002 VS	200	243.93 ab
F _{Nozzle}	1.670*	
F _{Block}	0.707 ^{ns}	
LSD	63.656	
CV (%)	17.660	

Means followed by a different letter are different (LSD test, P≤0.05).

*Significant (P≤0.05).

ns: not significant.

tion (100 L ha⁻¹) had significantly higher average deposits on the plant, when compared with the lower application volumes (60 L ha⁻¹).

Table 4 shows the means values of spray deposition over the *B. pilosa* plants located within and between the rows at 30 DAS. It is evident that for the weeds located within the crop rows, only the TX nozzle (150 L ha⁻¹) provided the lowest deposition (less than 70.00 μL g⁻¹). However, the opposite occurred for the deposits on the leaves of *B. pilosa* located between the rows, where we found the highest values of deposits with the use of the TX nozzle (150 L ha⁻¹), followed by the XR nozzle (200 L ha⁻¹).

Comparing the spray deposition on the *B. pilosa* plants located within and between the rows, we verified that there was no statistical difference in the deposits provided by the XR (150 L ha⁻¹) and TJ60 (150 L ha⁻¹) nozzles. However, there were approximately 56.4 and 622.1% higher deposition on the weeds located between the rows than within the rows with the use of the XR (200 L ha⁻¹) and TX (150 L ha⁻¹) nozzles, respectively. Opposite results were obtained for the nozzles TX (200 L ha⁻¹) and TJ60 (200 L ha⁻¹) which provided 74.9 and 64.4% higher deposition in on the weeds

Table 4. Mean values of the spray deposition on *B. pilosa* plants located within and between the rows of a common bean crop at 30 DAS.

Nozzles	Spray volume (L ha ⁻¹)	Row	
		Row	Between row
XR 110015 VS	150	272.73 aA	231.11cdA
XR 11002 VS	200	262.25 aB	410.29 abA
TX VS 6	150	69.28 bB	500.25 aA
TX VS 8	200	378.88 aA	216.52 dB
TJ60 11002 VS	150	251.53 aA	360.25 bcA
TJ60 11002 VS	200	364.48 aA	221.76 dB
F _{Nozzle} (N)	0.731ns		
F _{Position} (Po)	4.668*		
F _{(N) x (Po)}	11.971**		
F _{Block}	1.499ns		
LSD	131.102		
CV (%)	30.90		

Means followed by a different capital letter in a row and the are different lower case letters in a column (LSD test, P≤0.05).

*Significant (P≤0.05).

**Significant (P≤0.01).

ns: not significant.

located the rows than within the between the rows, respectively.

Souza *et al.* (2007) mentioned that interference may occur in the deposition of spray droplets due to the stage of development of the plant, as the germination of weeds is irregular: on any given day, one can observe weeds in various stages and of various sizes. In addition, the small size of many weeds and their position in the field, whether or not they are near the crop, may also increase the variability of individual deposits. These authors also show that, in the standardization of weeds in the same range of dry mass or leaf area in different positions in the field (in-row and between rows), there are more deposits on the plants between the rows than on those located within the rows.

Similar to the observations for *B. pilosa*, the TX nozzle (150 L ha⁻¹) also provided the lowest spray deposition over the *B. plantaginea* plants located within the crop rows. The TJ60 nozzle (200 L ha⁻¹) produced the highest average deposition on

the *B. plantaginea* plants located between the rows (Table 5).

Tomazela *et al.* (2006) verified that the use of the XR nozzle with angles of -15° , -30° , 15° and 30° in the spray bar provided increases of the spray deposition over *B. plantaginea* plants of 55.3, 40.7, 53.4 and 70.6%, respectively, as compared to the angle of 90° that is often used in agricultural sprays.

In this study, considering the performance of each nozzle on the spray deposition over the *B. plantaginea* plants, it was found that only the XR nozzle (150 L ha^{-1}) showed no differences in the coverage of plants located within rows and between the rows of common bean at 30 DAS.

Comparing the spray deposition on the *B. plantaginea* plants located within and between the rows, we verified that there was no statistical difference in the deposits provided by the XR (150 L ha^{-1}) nozzle. However, there were approximately 463.6 and 85.3% higher deposition on the weeds located between the rows than within the rows with the use of the TX (150 L ha^{-1}) and

TJ60 (200 L ha^{-1}) nozzles, respectively. Opposite results were obtained for the nozzles XR (200 L ha^{-1}), TX (200 L ha^{-1}) and TJ60 (150 L ha^{-1}) which provided 75.8, 115.4 and 191.6% higher deposition in on the weeds located the rows than within the between the rows, respectively.

Souza *et al.* (2007) found that the flat fan nozzle (110° -SF-01), working at 250 L ha^{-1} , provided a spray deposition that was 34% higher for *B. plantaginea* plants at the 2-8 leaf stage and located between rows, when compared to the plants located in the rows of a soybean crop (V2-4 stage). It is important to emphasize that the diversity in leaf morphological that exists between *B. pilosa* and *B. plantaginea*, including the trichomes, stomata, cuticles and waxes, can have a great influence on the drop deposition and its adherence to the leaves and, consequently, on the absorption of the herbicide (Ferreira *et al.*, 2002; Procópio *et al.*, 2003; Monquero *et al.*, 2001; Costa *et al.*, 2005a; Costa *et al.*, 2005b). However, there are few available reports on morphological studies related to leaf anatomy and correlated with drop deposition over weeds.

Table 5. Mean values of the spray deposition on *B. plantaginea* plants located within and between the rows of a common bean crop at 30 DAS.

Nozzles	Spray volume (L ha^{-1})	Row	Between row
		($\mu\text{L g}^{-1}$ dry mass)	
XR 110015 VS	150	331.78 aA	306.49 bA
XR 11002 VS	200	483.69 aA	275.12 bB
TX VS 6	150	44.23bB	249.27 bA
TX VS 8	200	397.51 aA	184.56 bB
TJ60 11002 VS	150	465.49 aA	159.62 bB
TJ60 11002 VS	200	306.95aB	568.70 aA
$F_{\text{Nozzle}} (N)$	4.800**		
$F_{\text{Position}} (Po)$	1.698ns		
$F_{(N) \times (Po)}$	6.980**		
F_{Block}	1.854ns		
LSD	182.233		
CV (%)	40.28		

Means followed by a different capital letter in a row and the are different lower case letters in a column (LSD test, $P \leq 0.05$).

**Significant ($P \leq 0.01$).

ns: not significant.

Hess and Falk (1990) have proposed that the use of surfactants might be useful to solve the problem of herbicide deposition and absorption on those leaves where waxes or trichomes represent a negative influence.

Maciel *et al.* (2001) reported that the drop deposition on *Brachiaria decumbens* plants located under common bean plants of mixtures containing Aterbane (0,5% v v⁻¹) and sprayed by TX nozzles can provide 289.2 and 172.9% more coverage than the XR nozzle with or without the same surfactant, respectively. Thus, the umbrella effect provided by common bean plants during the herbicide spraying can be minimized when the surface tension is reduced and when the nozzles produce drops with smaller diameters. Alternatively, this proceeding may increase the occurrence of drift, as it is necessary that spraying activities be executed at the ambient conditions that are most favorable (Lima and Machado-Neto, 2001; Penckowski *et al.*, 2003).

Some studies showed that the effectiveness of herbicides was low when the spray volumes were below 50 L ha⁻¹, as compared to volumes greater than 180 L ha⁻¹; thus, the optimum spraying volume should be determined empirically for each type of herbicide (Mcmullan, 1995).

Tomazela *et al.* (2006) evaluated the deposition of drops using a XR nozzle for *B. plantaginea* plants at the stage of 2 to 3 leaves and observed that, as the spraying volume per hectare decreased, there were increases in the percentage of deposits on the plants and, concomitantly, decreases in the percentage deposited on the soil, indicating greater efficiency in reach the biological target.

In general, we conclude that, regardless of the nozzle used, the drift of spray solutions to the soil occurred mainly between the rows of the common bean crop and that this drift was intensified with the use of nozzles that offered a greater volume of application. The different nozzles evaluated did not influence the deposition of the drops on the bean plants at 30 DAS, except for the TX nozzle (150 L ha⁻¹), with the lowest average deposits.

In terms of the spray deposition on the *B. pilosa* and *B. plantaginea* weeds, we found that the spray nozzles evaluated provided large variations in individual deposits on the plants located both within and between the rows, possibly due to a lack of standardization of the stages of development of both species and the proximity of the weeds to the common bean crop.

Resumen

A.C.P. Rodrigues-Costa, D. Martins, N.V. Costa y M.R.R. Pereira. 2011. Depósitos de las gotas de pulverización sobre las malezas en frijol. Cien. Inv. Agr. 38(3): 357-365. Los fracasos en el control de malezas en frijol (*Phaseolus vulgaris* L.) pueden estar relacionados con inadecuadas técnicas de aplicación de herbicidas. Se determinó la cantidad de deposición de las gotas de pulverización en las plantas de *Bidens pilosa* L. y *Brachiaria plantaginea* (Link) Hitch., presentes en la línea y entre la línea de frijol. Se evaluaron 6 boquillas de pulverización: de abanico plano XR 110.015 (150 L ha⁻¹) y XR 11002 VS (200 L ha⁻¹), de cono TX VK 6 (150 L ha⁻¹) y TX VK 8 (200 L ha⁻¹) y de doble abanico plano TJ60 11002 VS (150 L ha⁻¹) y TJ60 11002 VS (200 L ha⁻¹). Se utilizó un diseño de bloques al azar con 4 repeticiones. Los resultados mostraron que la pérdida de caldo al suelo se produjo principalmente en las líneas de frijol y con mayor intensidad con el uso de volumen de aplicación de 200 L ha⁻¹. A los 30 días post siembra del frijol, la boquilla TX (150 L ha⁻¹) fue el único tratamiento que promovió depósitos

menores a 210,0 $\mu\text{L g}^{-1}$ de materia seca. Las boquillas de pulverización evaluadas mostraron un buen desempeño en la deposición de gotas en la maleza *B. pilosa* y *B. plantaginea* presentes en la línea y en la entre línea. Sin embargo, existió una gran variación en los depósitos individuales de ambas especies según su ubicación en relación al cultivo.

Palabras clave: Tecnología de aplicación, *Bidens pilosa*, boquilla de pulverización, *Brachiaria plantaginea*, *Phaseolus vulgaris*.

References

- Bauer, F. C., and C. G. Raetano. 2003. air-assisted boom sprayer and spray deposition on bean plants. *Scientia Agrícola*. 60: 211-215.
- Berni, R.F., V.O.F. Machado, G.R. Costa, G. Barata, and R. S. Paula. 1999. Avaliação da cobertura de gotas provocada por diferentes bicos de pulverização na cultura do milho e do feijão. *Pesquisa Agropecuária Tropical*. 29: 49-52.
- Chaim, A., P.J. Valarini, and L.C. Pio. 2000. Avaliação de perdas na pulverização de agrotóxicos na cultura do feijão. *Pesticidas: Revista de Ecotoxicologia e Meio Ambiente* 10: 65-74.
- Cobucci, T., and E. Machado. 1999. Seletividade, eficiência de controle de plantas daninhas e persistência no solo de imazamox aplicado na cultura do feijoeiro. *Planta Daninha* 17:419-432.
- Costa, N.V., D. Martins, R.A. Rodella, and L.D.N.C. Costa. 2005a. Droplet deposition during spray and leaf ph in aquatic weed control. *Scientia Agrícola* 62: 227-234.
- Costa, N.V., D. Martins, R.A. Rodella, and L.D.N.C. Costa. 2005b. Ph foliar e deposição de gotas de pulverização em plantas daninhas aquáticas: *Brachiaria mutica*, *Brachiaria subquadripara* e *Panicum repens*. *Planta Daninha* 23: 295-304.
- Cunha, J.P.A.R., M.M. Teixeira, R.F. Vieira, and H.C. Fenandes. 2005. Deposição e deriva de calda fungicida aplicada em feijoeiro, em função de bico de pulverização e de volume de calda. *Revista Brasileira de Engenharia Agrícola e Ambiental* 9: 133-38.
- Ferreira, E.A., S.O. Procópio, E.A.M. Silva, A.A. Silva, and R.J.N. Rufino. 2002. Estudos anatômicos de folhas de espécies de plantas daninhas. II - *Bidens pilosa*, *Emilia sonchifolia*, *Ageratum conyzoides* e *Sonchus asper*. *Planta Daninha* 20: 327-335.
- Hess, F.D., and R.H. Falk. 1990. Herbicide deposition on leaf surfaces. *Weed Science* 38: 280-288.
- Holloway, P.J. 1970. Surface factors affecting the wetting of leaves. *Pesticide Science* 1: 56-63.
- Knoche, M. 1994. Effect of droplet size and carrier volume on performance of foliage applied herbicides. *Crop Protection* 13: 163-178.
- Lima, P.R.F., and J.G. Machado-Neto. 2001. Otimização da aplicação de fluazifop-p-butil em pós-emergência na cultura de soja (*Glycine max*). *Planta Daninha* 19: 85-95.
- Maciel, C.D.G., R.T. Souza, R.H. Silva, E.D. Velini, and L.B. Lemos. 2001. Avaliação do depósito e distribuição da calda de pulverização em plantas de feijoeiro e *Braquiaria decumbens*. *Planta Daninha* 19: 103-110.
- Memullan, P.M. 1995. Effect of spray volume, spray pressure and adjuvant volume on efficacy of sethoxydim and fenoxaprop-p-ethyl. *Crop Protection* 14: 549-554.
- Monquero, P.A., P.J. Christoffoleti, J.A. Matas, and A. Heredia. 2004. Caracterização da superfície foliar e das ceras epicuticulares em *Commelina benghalensis*, *Ipomoea grandifolia* e *Amaranthus hybridus*. *Planta Daninha* 22: 203-210.
- Penckowski, L.H., M.J. Podolan, and R.F. López-Ovejero. 2003. Influência das condições climáticas no momento da aplicação de herbicidas pós-emergentes sobre a eficácia de controle de nabiça (*Raphanus raphanistrum*) na cultura de trigo. *Planta Daninha* 21: 435-442.
- Procópio, S.O., E.A. Ferreira, E.A.M. Silva, A.A. Silva, R.J.N. Rufino, and J.B. Santos. 2003. Estudos anatômicos de folhas de plantas daninhas de grande ocorrência no Brasil. III. *Galinsoga parviflora*, *Crotalaria incana*, *Conyza bonariensis* e *Ipomoea cairica*. *Planta daninha* 21: 1-9.
- Raetano, C.G., and F. Bauer. 2004. Deposição e perdas da calda em feijoeiro em aplicação com assistência de ar na barra pulverizadora. *Bragantia* 63: 309-315.
- Salgado, T.P., M.S. Salles, J.V.F. Martins, and P.L.C. Alves. 2007. Interferência das plantas daninhas

- no feijoeiro carioca. *Planta Daninha* 25: 443-448.
- Souza, R.T., E.D. Velini, and L.A. Palladini. 2007. Aspectos metodológicos para análise de depósitos de pulverizações pela determinação dos depósitos pontuais. *Planta Daninha* 25: 195-202.
- Taylor, W.A., and G.B. Shaw. 1993. The effect of drop speed, size and surfactant on the deposition of spray on barley and radish or mustard. *Pesticide Science* 14: 659-665.
- Tomazela, M.S., D. Martins, S.R. Marchi, and E. Negrisoni. 2006. Avaliação da deposição da calda de pulverização em função da densidade populacional de *Brachiaria plantaginea*, do volume e do ângulo de aplicação. *Planta Daninha* 24: 183-189.

